9. Site Operations and Maintenance

Needs to Know Criteria
▪ Relationship between (a) hydraulic loadings and surface crusting, (b) surface ponding and surface runoff
▪ Limiting traffic on land application sites
▪ Good cover crop management
▪ Factors to consider when selecting crops
▪ Importance of harvesting the cover crop
▪ Importance of maintaining proper soil pH
▪ Recognizing poor crop health
▪ Steps to take if a suitable vegetative cover is not present
▪ Hydraulic overload site conditions
▪ Leakage around piping and valves
▪ Recognition and significance of damaged ground water monitoring wells
▪ Recognition of properly constructed and properly protected wells
▪ Conditions under which site expansion may need to be considered
▪ Site operation and maintenance manual contents
▪ Record keeping—types of information to record daily site and the importance of keeping accurate and complete records
▪ Emergency action plan contents
▪ Steps to follow if a chemical spill or a release of wastes occurs
▪ Agency contacts in the event of a spill or release
▪ Controlling access to land application fields
▪ Prerequisites for allowing grazing
▪ How the following documents are used during the operation and maintenance of the wastewater land application site: Grazing Management Plan, Odor Management Plan, Waste Solids Disposal Plan, Emergency Action Plan
▪ What must be done if runoff occurs
▪ What can be done to control or mitigate ponding
▪ Methods or BMPs to control runoff
▪ Land application as a wastewater treatment method
▪ Management to prevent adverse environmental impacts

Needs To Know!

The main function of a land application system is the beneficial reuse of wastewater while protecting the quality of the land application site environment. Operators must ensure that all aspects of the operation are addressed, including the following:

- Reconnaissance of the site by the operator is vitally important, not only in site selection, but also to inspect the site for evidence of run-off and to collect samples and inspect crops.
- Soils and crops must be protected, so that continued use of the land application site is ensured.
- Ground and surface water must be protected to ensure the integrity of these resources.
- Sites must be protected from poor field operations that can result in destruction of soil structure.

- Sites must be protected from over-application of metals, nutrients, salts and other waste constituents that may adversely affect the soil/crop system.
- Adequate monitoring must be established to track the volume of applied wastewater and nutrients.
- Each facility should maintain an Operations and Maintenance Manual specific to that facility. The maintenance and management of the soils and crops at the facility should be specifically addressed in the manual, since the overall function of the system relies on these components.

This section presents guidelines for the operation, maintenance, and management of soil/crop system and land application equipment. Areas addressed include the following:

- soil management
- crop management
- management of wastewater application
- system component management
- environmental management

9.1 Soil Management

A properly designed land application system should make maximum use of each soil/crop system on the site. Existing soil limitations must be addressed, either by limiting loading rates (hydraulic, nutrients, etc.) or by totally eliminating certain areas due to unsuitable soils or inadequate buffer zones. Factors that should be taken into account when selecting a site and designing a land application system include the following:

- soil surface texture
- soil slope
- cover crop health
- crop type
- wastewater patterns

Even when a site has been carefully selected and investigated, soil-related problems can arise. The following situations may indicate that a problem is soil-related:

- seasonal ponding or surfacing of effluent, when wastewater application rates remain consistent
- ground water compliance problems
- problems in segregated areas of a field
- effluent surfacing away from the land application field

If these problems exist, the operator should adjust wastewater application rates, in accordance with the methods described in Section 7.

However, not all conditions can be remedied by such adjustments in operations. Some situations must be remedied by expansion of the land application site, which would involve a permit modification and detailed soil and other site characteristic information on the proposed area of expansion.

Wastewater application should be governed not only by weather conditions and soil moisture, but also by the condition of the soil/crop system at the site. As the soil/crop system changes, application rates must change accordingly. Examples of changes that might occur in the soil/crop system include the following:

- change of cover crops or management schemes
- chronic saturation
- buildup of thatch
- presence of soil crusting
- increased soil compaction
- health of the cover crop
- chemical changes in the soil

The soil/crop system must be carefully managed to avoid or minimize the following soil-related problems:

- ponding, runoff, surfacing, or prolonged saturation
- ground water mounding
- surface crusting
- compaction
- excess nutrients

Ponding, Runoff, Surfacing, or Prolonged Saturation

One goal of wastewater land application is to apply wastewater at a rate that will result in neither runoff nor saturated flow conditions. This means that the wastewater will slowly soak into the soil and be useful to the crop as both a water and nutrient source. Ponding, runoff, surfacing or prolonged periods of saturation are undesirable. If mechanical causes for these problems are ruled out, the problem may be a soil condition that can be corrected.

Periodic wetness, runoff, or ponding of effluent are typically the result of over-application of wastewater. The fact that a given site is permitted for 30 inches of wastewater application per year is no guarantee that these application rates can be maintained every year or at all times during the year: low areas that naturally receive more runoff must be loaded differently than areas on smooth upland positions, and effluent must be distributed to avoid localized ponding or overloading of a specific area. For example, if 30 percent of the spray nozzles are not working, the remaining portion of the field receives an increased volume of effluent. This localized hydraulic overloading may result in wastewater runoff (Figure 9-1) and/or insufficient treatment of wastewater in the soil/crop system.

Figure 9-1. Runoff from a wastewater land application site.

Wastewater Mounding

Even if wastewater soaks into the soil surface as desired, its downward movement may be impeded by a r*estrictive layer* (a layer in the soil that reduces permeability, such as hardpan). If so, additional irrigation events can cause the subsurface saturated zone to rise in the soil, resulting in wastewater mounding (as discussed in Section 3. page 3-8).

Depending on soil type, one to three feet of unsaturated soil are typically needed for wastewater treatment. If mounding results in saturated conditions within three feet of the soil surface, anaerobic conditions in the root zone can limit the growth potential of crops, resulting in insufficient treatment of wastewater because the water may flow laterally or surface at the ground.

An operator can readily check the level of a perched water table in fields or areas of concern:

- During times of expected high water levels in soils, you can use an auger or post-hole digger to open a hole in the soil to the depth of your interest. Usually, a hole 18 inches deep will be sufficient to indicate whether there is saturation to the soil surface.
- Sufficient time should be allowed for the soil water to move into the hole, generally an hour or so. If the water level is within 12 inches of the soil surface, you are in a situation where water additions (rainfall or irrigation) may result in rapid lateral subsurface flow, ponding, anaerobic conditions for the crop roots, and potential for runoff or discharge of wastewater.

A more permanent monitoring device can be established by inserting a piece of perforated plastic pipe with a removable cap into the soil. This monitoring device should be marked, so it is not damaged by equipment, or set at grade level and marked with flagging or orange paint. Such simple devices can easily assist the operator in making irrigation decisions that protect the soil/crop system from saturation.

Surface Crusting

Poor management practices can result in surface crusting: formation of a relatively impermeable layer at the soil surface. Such a layer can be created by excessive thatch, improper application of organic matter, and destruction of surface soil aggregates.

Surface Crusting Caused by Thatch

One cause of surface crusting that is often overlooked is the accumulation of thatch, which is a layer of dead and living grass shoots, stems, and roots. Excessive thatch buildup can result in reduced infiltrative capacity of the soil, acting as a barrier to added water. It can also serve to block the transfer of air (oxygen) to plant roots, causing further stress to the cover crop. In extreme conditions, anaerobic activity or algae growth can occur on the thatch buildup: an organic or slime layer may form a *clogging mat* and further decrease water infiltration. If a large enough portion of the site is affected, the result is increased load on the remainder of the site. For all these reasons, thatch buildup should be monitored and removed promptly if a problem is noted.

It is easier to prevent thatch buildup than to try to remove it. Prevention can be accomplished by frequent mowing, removal of mowed vegetation, and operating the site so that wet conditions at the soil surface are not chronic. Removal of thatch may be performed with special rakes or soil aeration tools. In extreme cases, disking of the field or complete replanting may be necessary. Since these activities result in significant damage or removal of the cover crop, there will be some start-up time required with a new crop, during which irrigation volumes must be reduced due to the potential of increased runoff and soil erosion.

Surface Crusting Caused by Improper Application of Organic Matter

As we have learned, organic matter is found in most wastewaters. It may be in the form of large suspended solids, dissolved carbonaceous compounds, or both.

If improperly applied to the soil surface, suspended solids in wastewater may also generate a clogging mat, composed primarily of anaerobic bacteria, on the soil surface. Once established, this slime limits the exchange of oxygen in the soil, and anaerobic conditions will develop under the soil surface.

Oxygen transport into and through the soil is critical for the degradation of organic additions. If wastewater is to receive sufficient treatment, it is essential that the soil drain adequately. Under waterlogged conditions, oxygen diffusion may be severely restricted. Sufficient time is needed for the oxygen to diffuse into the soil and for the microbial degradation to occur.

Hence, the irrigation frequency is quite important and organic overloading can occur if the above loading factors are not properly managed.

Soil Crusting Caused by Destruction of Surface Soil Aggregates

Soil crusting can also be caused by destruction of surface soil aggregates, especially when soil is exposed and left bare to heavy rains. Fine soil particles disperse and seal the soil surface, which can become quite impermeable to infiltration if areas of bare soil occur at the wastewater land application site. Once soils become crusted it can be difficult to establish plants or seedlings.

Dealing with Surface Crusting

In areas where crusting has occurred, it is important to restore aeration to the plant root zone and to provide favorable conditions for crops as well as for soil microorganisms involved in the treatment of the wastewater. Surface crusting can be easily reversed by mechanical tillage to break up the soil surface or by raking to remove thatch.

However, because additional traffic increases the potential for compaction of subsurface layers, the crust should be broken using the lightest possible equipment, and the area must be reseeded. Any efforts to reestablish cover crops on areas of crusted soils or thatch buildup should be performed at the most ideal time for planting the crop that is to be used.

Compaction

As discussed in Section 2, heavy traffic (especially on wet soils) can cause soil compaction, destroying soil pores and reducing aeration and the effective permeability of the soil profile. Both surface and subsurface drainage and aeration are essential to maintain an aerobic soil environment suitable for wastewater treatment. The maintenance of a stable soil structure is an important means of maintaining good drainage and aeration. Therefore, traffic over a land application field should be limited only to equipment or vehicles that are absolutely necessary for operation and maintenance.

Once soil is compacted, tillage may be necessary. One of the principal objectives of tillage operations is to maintain or enhance the water infiltration capacity of the soil surface as well as the air exchange within the entire soil profile. It may be necessary to chisel very deeply (1.5 to 2.0 feet) to loosen the subsoil. Impermeable pans formed by vehicular traffic (plow pans) or by cementation of fine particles (hard pans) can be broken up by subsoiling equipment that leaves the surface undisturbed and protected by vegetation or stubble. To be effective, however, the subsoiling equipment must completely break through the pan layers. This is difficult if the pan layers are more than one foot thick.

Local soil conservation district personnel should be consulted regarding tillage practices appropriate for specific crops, soils, and terrain.

Excess Wastewater Constituents

Monitoring the flow and constituent concentrations of the wastewater are typical requirements of a wastewater land application permit, so the concentration of waste constituents in the wastewater and the expected volume of wastewater should be analyzed prior to site evaluation and periodically during operation of a land application system. Monitoring the flow and constituent concentrations of the wastewater are typical requirements of a wastewater land application permit. Metals, such as copper, zinc, and manganese, or other wastewater components, such, as salts, pH, oils and grease, and organic and inorganic chemicals may prove to be limiting, depending on the crops planted at the land application site.

Likewise, if the plant species at the land application site is changed, wastewater characteristics must be assessed to determine if the selected plants are appropriate. When selecting crops, the amount of water that the crop needs for optimum growth must also be considered.

Significant levels of certain wastewater constituents may indicate the need for additional treatment of the wastewater prior to land application. It is beyond the scope of this manual to discuss all possible limitations that may be encountered with a wastewater land application site.

Excess Salts

The application of wastewater containing soluble salts, such as chlorides, sulfates, potassium, calcium, manganese, and especially sodium, can be detrimental not only to the crops being grown on the site, but to the soils as well. A buildup of sodium in the soil can reduce the permeability of the soil by causing dispersion of the clay minerals. Reduced permeability often results in poor internal soil drainage and aeration, which can cause stress to the cover crops as well as ponding and waterlogged soils that do not provide adequate wastewater treatment.

It may be possible (but difficult) to renovate soils with high sodium concentrations. It is preferred to minimize the risk of possible sodium overload.

Salts in soil can affect the soil in several ways:

- adversely affect soil structure
- upset soil-water balance and interfere with plant root growth and the plant's ability to use water and nutrients
- leach to ground water
- affect or reduce seed germination

The detrimental effects on plants result not only from the high salt contents, but also from the level of sodium in the soil, especially in relation to levels of calcium and magnesium. To understand the management options to restore or prevent damage to the soil, you must first understand the difference between saline and sodic soils:

Saline Versus Sodic Soils

- *Saline soils* contain concentrations of neutral soluble salts sufficient to interfere with the growth of most plants. When large amounts of dissolved salts are brought into contact with a plant cell, water will pass by osmosis from the cell into the more concentrated salt solution. The cell then collapses, ultimately leading to cell death and eventually plant death.
- *Sodic soils*, dominated by active sodium, exert a detrimental effect on plants in four ways:
    - caustic influence of the high pH, induced by the formation of sodium carbonate and bicarbonate
    - toxicity of the bicarbonate and other anions

  - the adverse effects of the active sodium ions on plant metabolism and nutrition and the low micronutrient availability due to high pH

- oxygen deficiency due to breakdown of soil structure in sodium-dominated soils

The influence of soil pH on wastewater land application activities is further discussed in Section 2.

Plant Tolerance

Plant tolerance to saline and sodic soils depends on a number of interrelated factors, including the physiological constitution of the plant, its stage of growth, and its rooting habits. It is interesting to note that old alfalfa is more tolerant of salt-affected soils than young alfalfa, and that deep-rooted legumes show a greater resistance to such soils than the shallow-rooted ones.

Evaluating Soils Conditions: SAR

To evaluate the condition of the soil, the nature of the various salts, their proportionate amounts, their total concentration, and their distribution in the soil profile must be considered. The structure of the soil and its drainage and aeration are important as well.

Prevention of the problem is very important. Once sodium and salt damage occurs to the soil, it is a slow and tedious procedure to restore the soil to its original condition. To prevent such damage, it is helpful to know the sodium concentration in the irrigated wastewater.

As discussed in Section 2, a ratio of the sodium concentration to the concentrations of calcium and magnesium is called the *sodium adsorption ratio* (SAR) and the value of this ratio is a good indicator of potential soil problems. For soils, the SAR test is run on a saturated paste extraction of the soil. The SAR test may also be run on a wastewater sample.

Sodium adsorption ratios in wastewater range from very low (less than 1) to several hundred. Industries that are especially prone to having SAR problems are the food processing industry, industries that use sodium hydroxide as a wash or disinfectant, or other operations using a form of sodium. *A SAR of 10 is generally considered an upper level for safe operation*. There are, however, many variables that go along with the SAR that will determine if problems will be expressed in the soil.

A SAR of 5 in wastewater should be a "red flag" to an operator. At this level, there should be some attention to the sodium issue to ensure that future problems can be minimized. If the SAR exceeds 5, an operator should determine if excess sodium in the wastewater stream can be reduced. Soil samples should also be analyzed for SAR to help determine if the soil sodium activity level is approaching a problem level. Individuals with technical expertise should be contacted if the operator is not experienced with these issues.

Evaluating Soil Conditions: ESP

Exchangeable sodium percentage (ESP) is another evaluation that can be used to determine possible excess sodium concentration in the soil itself. The ESP is the percentage of the soil's cation exchange capacity (CEC) that is occupied by the sodium cations. This determination can be made from a typical soil fertility evaluation.

Example:

The CEC of a soil is 8.9 milliequivalents per 100 grams of soil (meq/100 cm^3), and the Na is 0.2 meq/100 cm^3. What is the exchangeable sodium percentage?

$$ESP = \frac{\text{Na concentration}}{\text{CEC}} * 100\%$$

Figure 9-2. Calculating Exchangeable Sodium Percentage.

$$ESP = \frac{0.2\ \text{meq}/100\ \text{cm}^3 * 100\%}{8.9\ \text{meq}/100\ \text{cm}^3} = 2.25\%$$

An ESP level of *15 percent or higher is typically used to denote a level of concern*, where salt damage may occur both to the crop and to the soil structure. Levels from 10 to 15 percent should cause the operator some concern, and should justify the need to take remedial action (described above) before long range problems occur. The ESP ratio evaluation should be used in conjunction with calculating the SAR of the wastewater and the soil to ensure that salt buildup does not limit or restrict the long-range use of the site.

Improving Productivity of Saline and Sodic Soils

Three kinds of general management practices have been used to maintain or improve the productivity of saline and sodic soils:

- flushing of the salts
- conversion of some of the salts to harmless forms
- designated tolerance

In the first two methods, an attempt is made to eliminate some of the salts or to render them less toxic. In the third, the salts concentrations are not manipulated; rather, crops tolerant of high salt concentrations are grown. These practices are described in more detail in the following:

- *Flushing (Salt Removal)*-The most common methods used to free the soil of excess salts are installation of drainage systems and leaching or flushing. A combination of flooding after field drainage ditches have been installed is often the best method. The salts that dissolve are leached from the soil profile and drained away. However, the irrigation water used must not be high in soluble salts, especially sodium.

Note: If a facility is considering this method, it is important to contact DEQ to discuss the proposal in detail. The facility may need to request an exception to the hydraulic loading rate limits set forth in their wastewater land application permit. Any request for an exception must still achieve the objectives of protecting public health and preserving the beneficial uses of surface and ground water.

- *Conversion*-The use of gypsum on sodic soils is commonly recommended for the purpose of exchanging Ca^{2+} for Na^{+} on the clay surface and removing bicarbonates from the soil solution. Several tons of gypsum per acre are usually necessary. The soil must be kept moist to hasten the reaction, and the gypsum should be thoroughly mixed into the surface by cultivation, not simply plowed under. The treatment must be supplemented later by a thorough leaching of the soil with low-salt irrigation water to leach out some of the sodium sulfate.

Note: As with flushing, a facility considering this method should contact DEQ to discuss the proposal in detail.

- *Tolerance*-The use of salt-resistant crops is another important management tool. Although salt-tolerant crops are not considered "traditional" recipients of wastewater, many of the crops are high in value and could have the added advantage of income for a wastewater facility. For example, cotton, sorghum, barley, rye, sweet clover, and alfalfa are particularly tolerant. A crop such as alfalfa, once it is growing vigorously, may maintain itself in spite of increased salt concentrations in the soil that may develop later. The root action of tolerant plants is exceptionally helpful in improving the condition of sodic soils. Aggregation is improved and root channels are left, through which water and oxygen can penetrate the soil. Table 9-1 lists forage grasses and legumes and their various levels of salt-tolerance.

Excess Oil and Grease

Oils and grease are organic compounds, and, in concentrations typically seen in domestic wastewater they pose no problem to the soil organisms that ultimately break down the organic compounds. However, significant inputs of oil and grease can cause problems in a wastewater land application system, both with equipment operation and the soil/plant environment. If oils and grease are allowed to build up in the soil, the result is the clogging of soil pores to the extent that infiltration of water and air into the soil are reduced. This results in stress to the cover crop as well as increased potential for wastewater ponding and runoff. If oil and grease in the effluent exceeds 50 mg/L, then a process for oil/grease separation should be used to pretreat the land applied wastewater.

Table 9-1. Salt tolerance of forage grasses and legumes 1/ 2/ [from National Range and Pasture Handbook].

Good salt tolerance, 12 to 6 millimhos/cm	
Alkali sacaton	Rescuegrass
Barley	Rhodesgrass
Bermudagrass	Saltgrass
Birdsfoot trefoil	Tall fescue
Canada wildrye	Tall wheatgrass
Nuttall alkaligrass	Western wheatgrass
Moderate salt tolerance, 6 to 3 millimhos/cm	
Alfalfa	Perennial ryegrass
Beardless wildrye	Reed canarygrass
Big trefoil	Rye
Blue grama	Smooth bromegrass
Dallisgrass	Sour clover
Hardinggrass	Strawberry clover
Hubam clover	Sudangrass
Meadow fescue	Tall meadow oatgrass
Milkvetch, cicer	Wheat
Mountain bromegrass	White sweetclover
Oats	Yellow sweetclover
Orchardgrass	
Poor salt tolerance, 3 to 2 millimhos/cm	
Common white clover	Red clover
Meadow foxtail	Ladino clover
Alsike clover	Burnet

1/ Source: Bernstein, L. 1958. Salt tolerance of grasses and forage legumes. USDA Agricultural Information Bulletin 194.

2/ Within each category, the species are ranked in order of decreasing salt tolerance. The low in a higher category may be only marginally better than the high in the next lower category.

9.2 Crop Management

There are several reasons why cover crops are useful in protecting soil, water, and the environment. The majority of cover crops are forages, such as grasses. These cover crops are dense and grow close to the ground, providing a cover above the soil surface and a fibrous root system below the surface that accomplishes the following:

- results in better soil health, water holding capacity, cation exchange capacity, and soil microorganism populations, including earthworms, rhizobia, and bacteria;
- reduces the impact of raindrops on the soil surface, decreasing soil crusting, water runoff, and movement of soil particles off-site, thus less movement of fertilizer and pesticides into streams;
- extends the amount and depth of root exploration of the soil volume, which indirectly relates to plant water use and nutrient uptake.

Therefore, the establishment and maintenance of a vegetative cover should be one of the highest priorities of the system operator. The operator should routinely examine the health of the vegetative cover and take immediate action should there be a problem. Once plants begin to show stress, the problem is often well established and may require significant time and effort to correct. As with other management issues, prevention of problems is almost always easier than repairing problems.

Crops can be stressed by excessive water or by a lack of sufficient water. As discussed earlier in this section, crops can be stressed by excessive nutrient or salt applications. Conversely, crops can be stressed or damaged by insufficient plant nutrients or improper soil pH. Other factors include soil compaction and damage by maintenance equipment. The operator must be aware of the requirements of the cover crops and attempt to meet these requirements with a crop management plan. Such a plan will minimize the potential that the cover crops will be the limiting factor for the operation of the system (Figure 9-3).

Figure 9-3. Poor crop stand in a fescue pasture. The lighter areas indicate stunted or dying vegetation.

Maintaining good crop growing conditions will reduce both surface runoff losses and subsurface losses of plant nutrients, and will allow the wastewater system to perform as designed. Crop management involves the following activities:

- crop selection
- nutrient and physical management
- soil fertility management
- pest control
- best management practices
- troubleshooting

Crop Selection

Important factors in the selection of crops for land application systems include the following:

- nutrient requirements of the crops
- time and length of the growing season
- end use of the crop
- crop management requirements
- water tolerance of the crop
- use of seasonal overseeds
- soil type
- local climate conditions
- Using trees as receiver crops

Nutrient Requirements

The nutrient requirements of a crop impact system operation, both in terms of expense and time. If crops can be economically grown for harvest, such as in a commercial farming setting, and if the use of supplemental fertilizers is appropriate for the site, the time and cost expended fertilizing crops can be justified. Some crops are more tolerant of nutrient imbalances than others, but all crops will need some attention to maintain the health of the plants and assure proper system operation. In selecting crops, one should consult an agricultural manual that shows crop nutrient needs and timing during the growing season. Table 9-2 lists general nitrogen fertilization guidelines for various forage crops.

Table 9-2. Nitrogen Fertilization Guidelines (Zublena et al. 1996).

Commodity	PAN /RYE[1]
Corn (silage)	10-20 lb N/ton
Bermudagrass (hay[2,3])	40-50 lb N/dry ton
Tall fescue (hay[2,3])	40-50 lb N/dry ton
Orchardgrass (hay[2,3])	40-50 lb N/dry ton
Small grain (hay[2,3])	50-60 lb N/dry ton
Sorghum—sudangrass (hay[2,3])	45-55 lb N/dry ton
Millet (hay[2,3])	45-55 lb N/dry ton

[1]PAN=plant-available nitrogen. RYE=realistic yield estimate.
[2]Annual maintenance guidelines.
[3]Reduce nitrogen rate by 25 to 30 percent when grazing.

Time and Length of the Growing Season

Ideally, the crops grown should be selected to fit the times when wastewater is generated and wastewater application is required. A mixture of crop types may offer the operator flexibility in system management. Use of trees has also been increasing, as trees may offer nutrient and water uptake throughout the year.

The End Use of the Crop

To keep a cropping system viable, it must be harvested at regular intervals. If there is no end use for the crop, less attention may be given to the crop's needs, possibly resulting in poor system management. Therefore, having a use for the crop should be a goal of the system owner and operator. If forage crops are mowed and baled, and simply left in the field to rot, the nutrients are returned back to the site and not removed. Examples of uses for hay bales include use as a mulch to give away to local residents or for use on municipal property or as feed to livestock. Another use could be to make compost that can be used by the public. Crops with higher cash value can simply be sold as is. Wood products have infrequent harvest intervals, but there should be a planned market for those products if selected for use at the site.

Crop Management Requirements

Crops should be selected with a good understanding of their maintenance requirements. Is the crop perennial, or must it be re-planted every year or two? Does the crop require nutrient applications two times per year or eight times per year? Are there other tedious tasks that need to be performed in order for the crop to stay healthy?

Generally, the simpler the maintenance scheme for a crop, the better it can be managed. The use of trees as opposed to hay crops has increased, largely because hay requires mowing, drying, raking, and baling, which must be done during dry periods with no wastewater application.

Water Tolerance of the Crop

A crop that cannot tolerate the expected combination of applied wastewater and precipitation at the site should not be used. Some crops cannot tolerate soil saturation for very long, while other crops and grasses may even thrive in such conditions. Examples of crops, grasses, and trees that are especially water-tolerant include reed canarygrass, ryegrass, common Bermudagrass, tall fescue, sweetgum, sycamore, and bald cypress. Examples of crops that are very susceptible to soil wetness problems include alfalfa and corn.

Use of Seasonal Overseeds

Forage grasses can be classified as cool season or warm season. No grass crop covers both categories.

- Cool season grasses grow actively in the spring and fall. They may go dormant in the summer. Warm season grasses grow actively from mid-April through October 1, and are dormant through the winter.

If these seasonal crops are used, other grasses may be used temporarily as an *overseed* to help with nutrient uptake and wastewater treatment. An example is to overseed winter rye (a cool season grass) into Bermudagrass. Some forage species are not tolerant of this arrangement, and an overseeded species may seriously damage the main crop. Examples of grasses, forages, or grains that should be avoided as an overseeding include gamagrass, switchgrass, or bluestems.

Soil Type

The crop selected must be adapted to the soil types on the site. On a large site, it is likely that several soil types exist; therefore, it may be necessary to use several crop types. Soils with heavy clay will stay wet longer after irrigation and rainfall events, and the crops must be able to handle these conditions. Sandy soils do not hold water and nutrients, therefore a drought-tolerant crop will survive better, and split applications of fertilizer may be needed.

Local Climatic Conditions

The crop must also be adapted to the local area. Sometimes, crops are selected for their nutrient removal ability or ability to stand wet conditions, but they may not tolerate the soils or climate. All factors must be considered to select a crop that can be adapted to the site and wastewater applications, and can be managed efficiently.

Using Trees as Receiver Crops

Using trees as receiver crops at land application sites is increasing in popularity. Application of wastewater to forestland offers a viable alternative for the beneficial reuse of nutrients, wastewater, and other waste constituents, while producing marketable wood products.

Under short rotations, trees can be whole-tree harvested, removing the nutrients from the site in a non-food chain product. Under medium to longer rotations, high value solid-wood products, such as lumber or veneer can be grown.

Crop possibilities include ornamental trees and shrubs (ball and burlap) grown for three to six years and removed as thinnings or as an entire crop. For harvested tree crops, a second rotation will result from *coppice* (sprouts) from the existing root systems. Coppicing will result in intermediate tree cover and a continuance of vegetative cover on the site without replanting.

Phosphorus uptake in trees also compares favorably to high yield grass crops. Prior to utilizing wastewater for tree irrigation, a silvicultural plan (a plan covering the care and cultivation of the trees) prepared by a qualified silviculturist is typically prepared for DEQ review and approval.

Nutrient and Physical Management

Once a cover crop has been selected, it must be established and properly managed to ensure that the crop thrives and functions as an efficient component of the treatment system:

- Cover crops should be planted at the best possible time. Time of planting is important because the survival rate of developing seedlings is related to the time at which stress occurs from drought, freezing, or competition for light and nutrients. If no such stress occurs, or if it occurs after seedlings are well established, survival and production losses can be minimized.
- Although many of the nutrients required by crops can be supplied through the application of wastewater, wastewater may not supply all the necessary plant nutrients. Nutrient application rates and timing of applications must be appropriate for the selected cover crop. Receiver crops vary in their ability to

utilize nutrients. In systems where the wastewater has high concentrations of nutrients, nutrients may limit the application rates. Wastewater application systems that are nutrient limited should time application events to appropriate stages in plant growth.

- Operators must understand the agricultural operations and schedule their wastewater application to allow for events (harvesting and grazing, for example) during which no wastewater can be applied to a site.
- Sampling to assist in nutrient management decisions is recommended even if not required by the system permit. Table 9-3 describes rates and timing of nitrogen applications for optimum uptake by various cover crops.

Table 9-3. Nitrogen Rates and Timing of Effluent Application to Minimize Soil Leaching Losses and Luxury Consumption by Forage Plants (Green & Mueller 1996).

Forage type	Typcial Annual Yield Range (tons/A)	Pounds of PAN N per Ton of Yield	Timing of Applications
Bermudagrass			
All pasture	4-5	30-40	At green-up in mid April, thereafter at 3 to 5 week intervals until Sept. 15
All hay or silage	5-8	40-50	At green-up in mid April, thereafter at 4 to 5 week intervals until Sept. 15
Pasture + overseeded	5-6	30-40	For bermudagrass same as above. For rye, Oct. and Feb. with rye in Sept. or Oct.
Fescue			
All pasture	2-4	30-40	1/3 Feb. 15-28; 1/3 April 1-15; 1/3 Sept. 1-15.
All hay or silage	3-5	40-50	1/3 Feb 15-28; 1/3 after first cut; 1/3 in Sept.

- Cover crops must be managed to reduce soil erosion and nutrient losses. Perennial grass sods are particularly effective in this regard. When a field has a thick perennial cover, there is far less runoff, and therefore, less chance for fertilizers to be washed away. In addition, most perennial grasses form dense root systems, which effectively serve as filters to remove contaminants before they can seep into the ground water. Even if a given field is used for row crop production, forages may be used in conjunction to reduce erosion. Grassed waterways, grassed terraces, strip cropping, and long-term rotations utilizing forages are good examples.
- The soil/crop system completes the beneficial reuse of wastewater. Nutrients and other waste constituents supplied to the crops through wastewater application are incorporated into plant tissue. Therefore, it is important that the crop and its nutrients be removed through harvest. The soil can store some nutrients and metals, but its capacity is limited. Removal of the crop and its stored nutrients is essential. Otherwise, nutrients are returned to the soil as crop residues. Failure to remove the crop can lead to excessive nutrient levels on the site, potential plant toxicity, and potential surface water or ground water contamination problems.

Pest Control

Crops must be periodically scouted for pests. A discussion of all possible pests on all crops that may be grown on wastewater land application sites is beyond the scope of this manual, but there are good resource guides and technical experts with the Department of Agriculture and the Cooperative Extension Service that can assist with this problem.

Any individual responsible for purchasing and applying restricted pesticides must be licensed by the State of Idaho. Restricted use pesticides must be used in accordance with label directions, and only licensed applicators can apply certain restricted use products.

Pesticides in ground water may result from problems, such as spills or backsiphoning, that occur when pesticides are mixed or loaded. These problems present "point sources," or small areas of high concentrations of pesticides that can contaminate large areas of ground water over time. Point source contamination can be located and cleaned up.

Good construction and maintenance of the pesticide mixing and loading area can prevent most of these problems, but pesticides may also be making their way into ground water from fields where they are applied. Applied pesticides can leach or move through the soil with water as it percolates down to ground water. The likelihood of a pesticide moving downward depends largely on its solubility, or its ability to dissolve in water. If a pesticide is highly soluble, it is more likely to reach the ground water. On the other hand, many pesticides, even some that are soluble, are likely to stick to soil particles by adsorption. Thus, if the probability of adsorption is high, less of the pesticides will leach.

Proper management of pesticides should be practiced to protect our water supplies. When applying pesticides, do the following:

- read container labels correctly
- use the lowest effective rate listed on the label for any one application; the assumption that "if a little will do a little good, a lot will do a lot of good" is a fallacy
- correctly identify pests, so that you use the proper pesticide and do not wastefully apply inappropriate materials
- sweep small amounts of fertilizer or pesticide granules that may fall on impervious areas, such as sidewalks and driveways, into a vegetated area;
- calibrate spreaders and sprayers, so that you know how much pesticide you are applying to an area
- learn about alternative pest control measures, such as beneficial insects, crop rotation, residue destruction, varietal resistance, proper planting dates, and companion cropping systems that may be good alternatives for your pest management problem

For more information about pesticides application, contact your local Cooperative Extension Service Center.

Best Management Practices

A *best management practice* (BMP) can be any practice that reduces the movement of waste products (including odors) away from the wastewater land application site, and into ground or surface water or to other properties. Best management practices are structural or operational practices that help you operate a wastewater land application system with the least chance of negative impacts on on the environment. Crops as well as crop residues, cultural practices and structures are used, alone or in combination, to hold the soil in place and allow water to move into it rather than to run off the surface.

Best management practices relating to nutrient management are those practices that optimize nutrient uptake by plants and minimize nutrient impact on the environment. These are very site specific: a BMP in one place may not offer the same benefits in another location. Therefore, specific BMPs may or may not be mandated in regulatory documents. A trained agronomist or soil scientist is the best resource to assess whether a particular BMP is appropriate for your situation if it is not already included as a condition of the system permit.

BMPs at a wastewater land application site may include the following:

- **Performing Soil Tests**. Nutrients should be applied to soils only as necessary. To know the soil's nutrient-supplying capacity, you must have it analyzed by a soil test laboratory that uses testing procedures developed specifically for your soil conditions.
- **Following Soil Test Recommendations**. A soil test report indicates the amount of nutrients that the soil can supply and recommends the amount, if any, needed from other sources. The test also recommends appropriate amendments (such as lime or sulfur) to adjust soil pH to the proper range for plant growth. All of the recommendations should be followed, because a deficiency of one nutrient or an undesirable soil pH will limit crop response to the other nutrients.
- **Setting Realistic Yield Goals**. All fertilizer recommendations assume a certain yield goal for the crop to be grown. Some laboratories ask for your goal, whereas others use an average number. The yield history of a field is the best guide to realistic expectations. Also, county soil surveys include crop yield estimates by soil series. Factors, such as the soil's moisture supplying capacity, should be considered.

  Do not over-apply nutrients in the quest for unrealistic yields. Applying excessive amounts of nutrients is a waste of money and can contribute to water pollution. Over-applying nitrogen is especially risky, since it can easily be lost from the soil.
- **Applying Nitrogen and Phosphorus Correctly**. Nitrogen and phosphorus from fertilizer application are less likely to be lost by erosion or runoff if they are banded directly into the soil or applied to the soil surface and promptly mixed into the soil by disking, plowing, or rotary tilling. Subsurface banding also makes it possible for nutrients to be placed where the crop can make the best use of them.

  Surface application of nitrogen and phosphorus without incorporation is the least desirable method of applying fertilizer, but it is often used for pastures, lawns, turf, and other perennial crops. Because phosphorus is relatively immobile, phosphorus should be incorporated into the soil before perennial crops are established. Where surface application is unavoidable, minimize the use of phosphorus. Aeration equipment can be used to improve soil infiltration and nutrient movement into the soil. The application method (surface applied or banded) has little effect on losses of nitrogen by leaching.

- **Timing Nitrogen Applications Appropriately.** The timing of application is more important with nitrogen than with any other nutrient, because nitrogen is applied in large amounts to many crops and is very mobile. Phosphorus, on the other hand, is more stable once it is mixed into the soil and can be applied when most convenient. Timing of nutrient application to coincide with plant growth requirements increases uptake efficiency and reduces exposure of applied nutrients to surface runoff and subsurface leaching. Optimum time of application depends on type of crop, climate, soil conditions, and chemical formulation of the fertilizer. Fall application of nitrogen can result in surface and subsurface losses of nitrogen, especially on sandy soils.

- **Controlling Erosion**. All nutrients can be lost when soil is eroded, but phosphorus is especially vulnerable. The primary way to prevent phosphorus loss is to control erosion. With few exceptions, if no sediments leave the land, little phosphorus leaves. Many erosion-control BMPs can be used in various cropping systems. A conservation farm plan providing for erosion control should be developed with assistance from the Natural Resources Conservation Service, USDA, and your county Cooperative Extension Service agent. Some specific practices include the following:

  - **Maintaining vegetation on ditch banks and in drainage channels**. Try not to disturb vegetation in drainage channels such as ditches and sod waterways. If necessary, construct ditches larger than needed so the bottoms can be left vegetated to trap sediment and other possible pollutants. Seed ditch banks and prevent ditch bank erosion by proper sloping and by diversion of field runoff water.

  - **Sloping field roads toward the field; seeding roads with a permanent grass cover**. Water erosion and dust from traffic on field roads contribute significantly to soil loss and potential pollution. Do not plow field roads when preparing land. Shape roads for good drainage, and seed them with a perennial grass where possible. Direct field road runoff toward the field or into a sodded waterway and away from any bordering ditch or canal.

  - **Shaping and seeding field edges to filter runoff as much as possible**. Do not plow up to the edge of the field, especially along ditches or canals. Leave a buffer strip along drainage ways, and establish a perennial sod. Shape and seed hoe drain outlets to filter runoff.

  - **Using windbreaks and conservation tillage to control wind erosion**. Wind erosion can be minimized by leaving the soil surface rough, maintaining crop residue on the soil surface, bedding to trap wind-blown sediments, keeping the soil wet, or maintaining a cover crop.

  - **Maintaining a soil cover.** Leave crop residues on the soil surface during the winter. Do not till too early in the spring. Where feasible, use no-till methods, which may be the only way highly erodible land can be cropped without excessive soil loss. On soils that are subject to erosion or leaching, consider using a winter cover crop to reduce erosion and to take up nutrients, thereby reducing leaching. A cover crop used in this way is called a "trap crop," since it "traps" and recycles nutrients for use by later crops.

    - **Managing the soil for maximum water infiltration**. Maintain crop residues on the soil surface. If there is little crop residue left in the fall, establish a winter cover crop, but leave the soil surface rough enough to help trap wastewater. These goals can be accomplished by using high-residue crops in the rotation and by tilling carefully to prevent soil compaction.

- **Managing Non-Wastewater Flows**. Water management is closely related to erosion control, and some practices overlap. In this section we are referring to water from precipitation and snowmelt, not wastewater irrigation. In general, erosion is minimized when water flow is slowed or stopped. Some specific practices include the following:

    - **Slowing water flow**. Use contour tillage, diversions, terraces, sediment ponds, and other methods to slow and trap rainfall and snowmelt runoff. The carrying capacity of running water is directly proportional to the flow rate. When water is still, sediments can settle out. Production practices, such as installing water-control structures—flashboard risers, for example—on field ditches in poorly drained soils benefit water quality significantly by reducing downstream sediment, phosphorus, and nitrogen. Sediment and associated phosphorus settle out of the drainage water, and nitrogen can be denitrified or used by stream vegetation.

    - **Preserving buffer strips**. Leave buffer areas between fields and environmentally sensitive areas (see Figure 9-4). The amount of buffer needed varies with the cropping activity and the nature of the adjacent area. See Section 4, *Wastewater Disinfection & Buffer Zones*, for an in-depth discussion of buffer zones and the minimum buffer distances used in Idaho. Minimum buffer zones are typically specified in the facility's wastewater land application permit.

Figure 9-4. Riparian buffer zones lining stream banks.

- **Using appropriate crops.** Deep rooted crops, including alfalfa will scavenge nitrates that leach past the usual soil rooting zone. Used in crop rotation, following shallow rooted or heavily fertilized row crops, deep-rooted crops will recover excess nitrate from the soil and reduce the amount of nitrate available for leaching to ground water.

No single set of BMPs applies in all situations, but when properly carried out, BMPs can improve water quality. Many studies document water quality improvement in streams adjacent to where BMPs have been used in surrounding agricultural areas. If BMPs are not performing their functions as designed, you should contact a trained agronomist or soil scientist for advice on appropriate remedies.

Troubleshooting

Diagnosing the needs of plants is comparable in many ways to diagnosing human ills. The medical doctor observes the patient, obtains all the information possible with his questions, and then makes the appropriate tests, all of which are helpful in diagnosing the case. Similarly, the wastewater operator observes the plants, obtains information on past management, and may make tests on the soil or the plant; the success of the diagnosis depends on the operator's understanding of the fundamentals of plant and soil science and on a correct interpretation of the test results.

Diagnostic measurements of the ailing plant or soil are often classed as *trouble-shooting*. Plant and soil samples can and are being used for troubleshooting, but a more important application is in preventive measures. By the time a plant is showing stress, it may be too late. Consider the analogy of closing the barn door after the horse has left. To be proactive in crop management, you need to be familiar with stress symptoms of plants.

Many of the methods for evaluating soil fertility are based on observations of, or measurements on, growing plants. These methods have considerable merit because the plants act as integrators of all growth factors (aeration, fertility, moisture, pH) and are the products in which the operator is interested. Abnormal appearance of the growing plant may be caused by a deficiency of one or more nutrient elements (Figure 9-5).

If a plant is lacking in a particular element, characteristic symptoms may appear. This visual method of evaluating soil fertility is unique in that it requires no expensive or elaborate equipment and can be used as a supplement to other diagnostic techniques. Examples of stress symptoms are as follows:

- Complete crop failure at seedling stage.
- Severe stunting of plants.
- Specific leaf symptoms such as changes in coloration appearing at varying times during the season.
- Delayed or abnormal maturity.
- Obvious yield differences, with or without leaf symptoms.
- Poor quality of crops.
- Poor germination, resulting in reduced stand coverage.

Figure 9-5. Sulfur deficiency in corn.

Be aware that in the field it is often difficult to distinguish among the causes of symptoms. Disease or insect damage frequently resembles certain micronutrient deficiencies; for example, leaf hopper damage is often confused with boron deficiency in alfalfa.

If symptoms are observed early and are correctly diagnosed, they might be corrected during the growing season. Crop health may suffer during the first year, but if the trouble is properly diagnosed, the symptoms may be fully corrected the following year.

If a cover crop is not present, or is in poor health, the operator should start the troubleshooting process. The following steps should be included when attempting to establish a cover crop or repair an existing cover crop:

1. Obtain a representative soil sample.
2. If crop is present but in poor shape, obtain a plant tissue analysis.
3. Check the area to see if prolonged saturation or soil compaction is a problem.
4. Select a crop or combination of crops suitable for the soil and site conditions, and one that can be managed in a wastewater application environment.
5. Select a crop that can be utilized locally or that has some return value;
6. Apply recommended nutrients and/or pH adjustments from the soil test results.
7. Prepare to plant or seed the crop, following all recommendations from the supply store, or contact local experts with the Cooperative Extension Service.
8. Implement BMPs recommended by a trained agronomist or soil scientist.

Management of Wastewater Application

Runoff can be avoided by maintaining the hydraulic loading rate within the levels acceptable by the soil/crop system.

Irrigation scheduling recommendations discussed in Section 7 should be followed.

Uniformity of Wastewater Distribution

Uniform distribution of wastewater effluent at the land application site is necessary to ensure that the entire land application site treats the wastewater, and to minimize overloading of any particular area. An operator should be familiar with the design plans for the facility, incluuding those design features that are intended to *not* to apply effluent evenly across a field. These design features may be required due to changes in soil conditions, slopes, or nearby drainageways.

In other cases, a site may be designed to receive uniform application across an entire field. The operator, however, knows that he/she cannot operate the system on that field or area at a uniform application rate without runoff or ponding of wastewater. Ultimately, it is the operator’s responsibility to operate the system within the requirements of the permit, which includes minimizing ponding and runoff.

Note: Any design modifications must be reviewed and approved by the Department of Environmental Quality.

Handling Bleed-off

Areas that are prone to wetness, or hydraulic overload include the heads of drainageways, soils with less permeable layers, compacted soil areas, areas with poor cover crops, and areas at the base of slopes. In most irrigation systems, a condition known as *bleed-off* is experienced when an operator ends an irrigation cycle. The water remaining in the distribution system will typically run to the lowest lateral and spray nozzle, and effluent will trickle out of this nozzle, sometimes for many minutes before the distribution lines are clear. This condition can result in local overloading of effluent and the possibility of ponding or runoff.

An operator can account for bleed-off in one of two ways:

- The irrigation cycle can be stopped early enough to anticipate the bleed-off and still have the soil in the bleed-off area absorb the effluent.
- The operator can install hardware to stop or spread out the bleed-off condition to minimize any localized overload.

Handling Chronic Hydraulic Overload

An area that is continually overloaded hydraulically will soon be obvious to the operator. The crop in that area may be taller or greener than in surrounding areas. If the situation is very bad, the local area may exhibit signs of crop stress or death due to chronic saturation. Another problem with chronic saturation is that it will eventually break down the soil structure, making the area even less permeable than it originally was. Crop harvest or maintenance procedures may have to be delayed or ignored if wet spots in the field are a problem.

Actions to minimize the potential for hydraulic overload include the following:

- changing nozzles in wet areas to nozzles that deliver less wastewater per unit time
- valving or capping individual risers so that they can be turned off to limit wastewater application or to reduce bleed-off
- valving individual lateral or manifold lines to accomplish wastewater application reduction
- using directional sprinklers to avoid slowly permeable areas or landscape positions
- using subsoiling equipment to revive the soil permeability
- enhancing the soil infiltration rate with good crop management and conservation practices

Winter Operation

Some land application systems operate throughout the winter months, while some systems operate exclusively during the warm growing season. For those systems shutting down completely during the winter, necessary precautions for freezing must be taken.

Note: For additional discussion of winterization of irrigation equipment, see Appendix D.

Operators of systems that function through the winter must be aware of the effects of cold weather on land application operations. During cold weather operation, the operator should inspect the fields prior to any application events and verify that the entire field has thawed and can accept wastewater. Cold temperatures result in slower drying times, and, therefore, reduced application depths, as discussed in Section 7. This may necessitate more frequent irrigation cycles of briefer duration when using a solid set or drip system—and different settings on mobile units, such as center pivots.

If water is allowed to remain in the irrigation lines on very cold nights, problems with freezing and equipment damage can result. The vulnerable areas are the risers, exposed valve boxes, above-ground piping, and suction or discharge piping from the pump (if not protected in a pump house or underground pump vault). On mobile systems, gun carts and center pivot towers are vulnerable to freeze damage. Most irrigation risers are equipped with underground drain or weep holes that allow the water in the riser to soak into the soil after the pump has been turned off and the pressure in the line decreases, but the operator must be sure that any above-grade valves are opened so that water is not trapped in the equipment.

Other units, such as center pivots, have caps or plugs that must be removed to allow drainage of the above-ground piping. Where above-ground piping is used, this pipe should be separated in several places, especially low areas, allowing water to drain from the pipe. Some units recommend purging some of the water with forced air; others do not require special freeze protection for the hose. All, however, require drainage of all fittings, turbines, and feed lines to protect the components and the warranty.

9.4 Management of System Components

The operator of a wastewater irrigation system must be familiar with the physical components that make up the system, understand how they work, and ensure a schedule of maintenance and troubleshooting actions to ensure proper operation of the system. This section focuses on the management of the following system components:

- land application equipment
- drainage systems
- soil and site components
- operation and maintenance manuals
- records

Land Application Equipment

An irrigation system is an expensive investment. Regular maintenance procedures will help keep your system operating properly for many years.

The original manufacturer's operation and maintenance manual or instructions for operation for each piece of irrigation equipment should be the primary source of information that provides the minimal required maintenance procedures. If the manual cannot be located, ask your local dealer or equipment manufacturer for a replacement.

Adherance to the following routine maintenance procedures will also reduce the risk of equipment failures that may lead to lost production time, crop loss, or that could result in a discharge of wastewater and damage to the environment.

Note: Appendix D contains an excellent publication that outlines the maintenance procedures for various types of land application equipment:

- annual maintenance procedures for sprinklers
- lubrication and fluids schedule for hard-hose travelers
- seasonal maintenance checklist for center-pivot and linear-move systems
- weekly, quarterly, and annual maintenance requirements for pumps
- inspection and maintenance schedule for electric motors that power irrigation pumps
- inspection and maintenance schedule for diesel motors that power irrigation pumps
- winterization and storage procedures for hard-hose travelers, center-pivot and linear-move systems, pumps, and engines that power pumps

Maintenance Procedures for Leak Detection

Very wet spots in a field, or along the piping to a field, can indicate a leak or break in the distribution network. Valve junction boxes are a common place to find leaks in the system. Leaks can be caused by freezing water in the lines or spray risers, damage from equipment, or failure of the part. Usually, a leak in the distribution system is easy to spot, as there will be a chronic wet area, regardless of the amount of spraying. Not only could this lead to a violation, due to wastewater ponding and/or runoff, but it also affects the performance of the rest of the system, where flow has been reduced.

Rotating sprayheads can be another place for equipment damage or malfunction. A sprayhead that is stuck in one position can easily result in a large amount of effluent being applied to a small area, soon resulting in runoff and/or ponding of wastewater. Sprayheads should be monitored frequently for proper operation. Something as simple as a piece of trash can cause a small diameter sprayhead to clog or remain stuck in one position. Sprayheads should be cleaned and maintained regularly. Where rust or corrosion prevents proper operation, replacement may be the best option.

Maintenance Procedures for Monitoring Well Protection

The area around groundwater monitoring wells must be protected:

- Highly visible markers may be used to warn equipment operators of the presence of the well.

- Using posts cemented into the ground to surround the well offers added protection against a well being hit with equipment.
- Damage from equipment includes cracked grouting, cracked or broken well piping, or broken locks or casings. This type of damage can result in the intrusion of surface water into the well and the contamination of groundwater. Such a well may have to be abandoned and another well constructed, costing much time and expense.

Monitoring well maintenance should include ensuring that caps are rust-free and locked at all times, that the outer casing is upright and undamaged, and that a clear, unobstructed path exists leading to each well.

Maintenance Procedures for Flowmeters

There are two important tools that can assist with irrigation scheduling. The first is a rain gauge (or set of gauges; the other is a well-calibrated flowmeter.

The flowmeter shows the volume of water that is being applied to the irrigation fields. Flow may be estimated by multiplying the pump capacity (gallons per minute) times the pump run time (minutes). The flaw in this technique is that it assumes that the pump is operating at full or "rated" capacity. This rarely is the case, due to such issues as pump wear, design of the system, friction losses that increase with pipe and nozzle wear or clogging, etc.

More accurate and therefore more useful flowmeter readings can consistently be obtained when the flowmeter is properly and frequently calibrated. Flowmeters must be regularly calibrated to the manufacturer’s specifications; using a flowmeter that has not been calibrated can create more problems than not having a flowmeter at all. Frequently, the dealer who sells the flowmeters has a specialist who can perform the calibration.

Flowmeters should be installed where the risk of corrosion from such devices as chlorinators or other chemical injection systems is minimized.

Flow meters are beneficial for ongoing maintenance of a land application system:

- Flowmeter readings help with irrigation scheduling and overall operation.
- Consistent usage of a calibrated flow meter is crucial in determining the amount of nutrients, salts, or other wastewater constituents that are being applied.
- Placement of a flowmeter on the influent side of the wastewater treatment system. Monitoring the influent flow shows if there are additional inputs of wastewater coming into the system. Additional inputs include illegal attachments to the collection system, infiltration, or inflow.
- Increased flow meter measurements in response to rainfall indicate there are leaks into the collection system that should be repaired. Use a smoke test to locate this type of leak.

  Removal of surface water inputs can often be quickly remedied. Leaks in underground piping due to old or broken collection lines can be very difficult and expensive to repair. Knowledge of and ongoing monitoring of these leaks helps the operator be aware of the overall system operation and provides information that should be used for irrigation scheduling. Knowledge of

Knowledge of additional flows is also important to minimize the potential hydraulic overloads to the land application fields that could cause ponding, runoff, or crop stress.

Maintenance Procedures for Plans and Specifications

The operators should have a set of system plans and specifications that specify all the equipment at the facility. These documents may specify the flow rate or application rate of the irrigation equipment with which you are working. However, those specifications are only valid as long as the pump is run at a certain speed, the equipment is new, the valves are all in the appropriate position, and there are no changes made to the system (such as adjusting valves or replacing sprayheads). Information presented in manufacturer's charts is typically based on average operating conditions with relatively new equipment.

Maintenance Procedures for Equipment Aging, Replacement, and Servicing

Discharge rates and application rates change over time as equipment gets older and components wear. In particular, pump wear tends to reduce operating pressure and flow. Nozzle wear results in an increase in the nozzle opening, which will increase the discharge rate while decreasing the wetted diameter. Extreme nozzle wear can result in pressure decreases substantial enough to affect sprinkler rotation. To ensure proper placement and rate of wastewater delivery, proper calibration of sprinkler equipment is necessary. Improper calibration and equipment maintenance will result in over or under application of wastewater and uneven nutrient distribution. Equipment calibration is discussed in Section 7.When replacing equipment, be sure that the replacement unit is satisfactory for the job. Replacement equipment must have the same rating, require the same power requirements, etc., so that it can be interchanged without affecting the overall functioning of the system.

All mechanical components will have some type of servicing requirements. Failure to perform regular maintenance results in equipment that does not last as long, and the possibility of premature failure during operation. Equipment failure at the wrong time could lead to a significant spill or leak of wastewater, causing a permit violation and possible threat to the surrounding environment.

Drainage Systems

The operator of a land application system needs to know if a separate surface water, ground water, or stormwater drainage system exists, either in the area being irrigated or the areas surrounding the land application site. Drainage can be a subsurface tile drainage system, surface ditching, or a combination of both. The operation of the wastewater land application system may be dependent on proper functioning of the drainage system; if such a drainage system exists, there should be references to it in the permit and the design plans and specifications. Often a drainage system is used to shed surface water away from a wastewater land application site.

The wastewater land application system owner must identify if the wastewater land application operators are also responsible for ongoing operation and maintenance of a separate drainage system or if other employees are responsible for the drainage systems. Drainage systems also need periodic attention to ensure proper operation. If an operator is responsible for proper maintenance of the separate drainage system, then the following checklist will help keep the drainage system working properly so as to prevent adverse impacts to the nearby wastewater land application system:

- Mark all drainage outlets and check frequently to be sure outlet is free of vegetation that could obstruct the outflow of water from the drainage system.
- Protect piped drainage outlets with animal guards to prevent stoppage from animals.
- Establish proper erosion control around the outlet to stabilize the drainage water and to ensure erosion does not damage the outlet area.

Erosion prevention is seen with the use of terraces and surface water diversions designed to shed surface water. Additionally, some may have a gravel or "French" drain to help with subsurface water removal (Figure 9-6). These surface water diversions must be properly vegetated to minimize erosion caused by the moving water. Erosion can readily change the slope or grade of the structure and affect its operation. On the other hand, if a surface water terrace or diversion becomes filled with sediment and loses its depth, runoff water designed to be trapped in the diversion may eventually overtop the structure. The original design criteria for all such structures should be maintained on the site, and the structure should be periodically monitored to ensure that it is at or near design specifications. If necessary, remove sediment or repair eroded areas to keep the structure at design criteria.

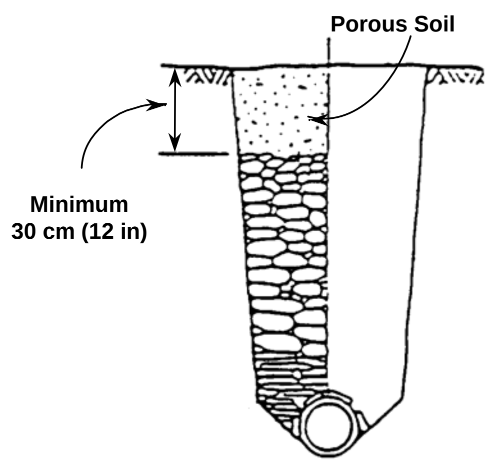

Figure 9-6. Cross section of a French drain.

Verify the drainage system is performing its function. After a soaking rainfall, inspect the outlets to ensure that the system is working. Any length of the drainage pipe can become clogged with sediment or broken by heavy equipment.

If the drainage system is not moving water as expected, inspect the entire system to look for places where clogs may have occurred. These may appear as wet spots along the drainage lines. Subsurface drainage systems can fail when the pipe is crushed or if holes or breaks occur. Also, if the system does not have the proper grade for water flow, as can happen with uneven settling, there can be problems with the drainage system working as designed. Uneven ground surface along the drain lines can also be an indication of a break in a subsurface piping network.

Soil and Site Components

To better accommodate wastewater and ensure proper treatment, you may need to consider expansion of the site if you experience one or more of the problems below:

- saturated soils
- ponding or runoff of wastewater
- excessive hydraulic loading rates
- excessive constituent loading rates
- crop stress due to excess soil moisture
- inability to maintain storage or freeboard in a lagoon, pond, or storage tank

Before resorting to an expansion, however, you should first determine that chronic wetness conditions are not a result of excess infiltration and inflow into the collection system or a correctable soil-related condition (as discussed earlier in this section).

Operation and Maintenance Manual

Each facility should maintain an *Operations and Maintenance* (O&M) *Manual* specific to that facility. The O&M manual (also referred to as a *Plan of Operation*) should be developed and used as an operator guide for actual day-to-day operations to meet requirements of the facility's wastewater land application permit and should include daily sampling and monitoring requirements to ensure proper operation of the wastewater treatment facility.

A *Plan of Operation Checklist* in DEQ's wastewater land application guidance document lists the minimum information that should be incorporated into the document. A partial list of items in the Plan of Operation Checklist is given below.

- General Plant Description: treatment design criteria, wastewater characterization, list of unit operations.
- Description, Operation, and Control of Unit Operations: description of process, major components and mechanical equipment, discussion of common operating problems and start-up procedures, equipment operating instructions with reference to equipment O&M manuals.
- Laboratory Testing: outline of sampling and testing program, interpretation and significance of lab results.
- Maintenance: preventative maintenance schedule, trouble-shooting guides, manufacturer's manuals.
- Records and Reports: daily operating log, maintenance records, laboratory records and reports, reporting permit violations and accidents.

- Personnel: staffing requirements and qualifications.
- Emergency Operating Plan: emergency numbers and emergency procedures.

All system components should have specification sheets, showing details of the units as well as operation and maintenance requirements. These are usually included in the O&M manual or attached as a supplement. If this information is not present, the operator should contact the manufacturers directly.

Typically, equipment will have a specification plate mounted somewhere that shows the company name, location, and model or serial number of the component. The manufacturer can be called for information on servicing the units. If the manufacturer is no longer in business, a local repair service may be able to provide service or information. If no information is available, you should service units similar to other units with like components.

Specific management plans, in addition to information provided in the facility O&M manual, may be required per the facility wastewater land application permit. Some example plans and important aspects of each are presented below.

- Grazing Management Plan: DEQ's land application guidance document specifies under what circumstances grazing of livestock on wastewater land application sites is allowed. Prior to any grazing activities, a Grazing Management Plan must be submitted to DEQ for review and approval. Items typically addressed in a Grazing Management Plan include: specifying the type and number of animals to be grazed, identifying the schedule for rotating animals through the site, preparing a nutrient balance, identifying the disinfection level of the applied wastewater, and identifying the minimum waiting periods prior to grazing animals on sites irrigated with wastewater.
- Odor Management Plan: An Odor Management Plan addresses all wastewater treatment systems, land application facilities, and other operations associated with the facility. The plan includes specific design considerations, operation and maintenance procedures, and management practices to be employed to minimize the potential for or limit odors. The plan also includes procedures to respond to an odor incident, if one occurs, including notification procedures.
- Waste Solids Management Plan: This plan describes how waste solids generated at the facility, including dredgings and sludges, are handled and disposed of in a manner to prevent their entry, or the entry of contaminated drainage or leachate, into the waters of the state, such that health hazards and nuisance conditions are not created; and to prevent impacts on designated beneficial uses of the ground water and surface water.
- Emergency Action Plan: This plan must be implemented in the event that a waste material from the facility is leaking, overflowing, or running off the site. (A more detailed discussion of Emergency Action Plans is presented later in this section.)

Records

System operation is enhanced by good recordkeeping. Maintaining records helps ensure that all permit conditions are met, that equipment is maintained at necessary intervals, and that the operator can make prudent wastewater land application decisions. Good recordkeeping can help an operator review system performance, identify problem areas, and it provides data in the event that permit modifications are needed.

The operator should review the system permit to determine recordkeeping requirements. Typically, these include the following:

- daily irrigation volumes, by hydraulic management unit
- flow measurements
- effluent sampling data
- ground water monitoring well sampling data
- soil monitoring data
- cover crop maintenance activities
- storage lagoon or pond freeboard measurements

Additionally, it is recommended that the operator keep a record or logbook of the following:

- equipment maintenance procedures
- equipment replacement
- documentation of site visits from inspectors or technical assistance professionals
- documentation of complaints and how they were addressed
- dates and locations of soil samples taken
- dates and locations of vegetation samples taken
- minor modifications to spray patterns

9.5 Environmental Protection

Wastewater application activities must be planned and managed to prevent adverse impacts to ground water, surface water, and public health. Adverse environmental impacts of land application can be minimized by proper management of the following:

- hydraulic and constituent loading rates
- timing of irrigation
- buffer zones
- wastewater constituents
- irrigation system performance

Adverse affects to the environment are minimized by maintaining buffer zones, controlling the quantity and quality of wastewater applied, and maintaining a healthy crop/soil system for final treatment of the wastewater. In addition, a wastewater land application site should be restricted to authorized personnel to prevent mishaps involving the public and to help ensure that the site and all equipment are protected from vandalism and theft.

Emergency Action Plans

As part of the permitting process, an emergency action plan may be required for a particular land application site. This plan must be implemented in the event that wastewater, other waste materials, or chemicals from the operation of the site are leaking, overflowing, or running off the site.

Note: You should NOT wait until wastes reach surface waters or leave your property to consider that you have a problem. You should make every effort to ensure that this does not happen. This plan should be available to all employees at the facility, since accidents, leaks, and breaks can happen at any time.

Your plan should follow the following four basic steps:

1. Stop the release of the waste material.
2. Assess the extent of the spill and note any obvious damages.
3. Contact the appropriate agencies.
4. Implement procedures to rectify the damage and repair the system.

Step 1: Stop the Release of the Waste Material

Spills must be contained immediately and the material should be pumped back to a storage facility or contained if possible. Facilities should have the necessary equipment and supplies to respond to a chemical or wastewater spill. Suggested responses to several problems are listed below:

- Storage pond overflow*:
    1. add soil to berm to increase elevation of dam
    2. pump wastewater to fields at an acceptable rate
    3. stop all additional flow to the structure
    4. call a pumping contractor
    5. make sure no surface water is entering storage structure

*__Note:__ These activities should be started when your storage facility level has exceeded the maximum design storage level.

- Runoff from wastewater land application field:
    1. immediately stop wastewater application
    2. create a temporary diversion or berm to contain the wastewater on the field
    3. pump the contained wastewater back to a storage structure
    4. incorporate wastewater to reduce further runoff
    5. evaluate and eliminate the reason(s) that caused the runoff

6. evaluate the application rates for the fields where runoff occurred

- Leakage from the wastewater distribution system (pipes and sprinklers):
    1. stop irrigation pump
    2. close valves to eliminate further discharge
    3. separate pipes to create an air gap and stop flow
    4. repair all leaks prior to restarting pumps
- Leakage from base or sidewall of lagoons or earthen storage structures (includes seepage as well as flowing leaks):
    1. dig a small well or ditch to catch all seepage, put in a submersible pump, and pump back into storage area
    2. if holes are caused by burrowing animals, trap or remove animals and fill holes and compact with a clay type soil
    3. other holes may be likewise temporarily plugged with clay soil

Note: Problems with lagoons and earthen storage structures require the consultation of an individual experienced in the design and installation of lagoons for permanent repair measures.

Step 2: Assess Spill Extent and Damages

Assess the extent of the spill and determine damages by answering the following questions:

- Did the wastewater reach any surface waters?
- Approximately how much was released and for what duration?
- Any damage noted, such as employee injury, fish kills, or property damage?
- Did the spill leave the property?
- Does the spill have the potential to reach surface waters?
- Could a future rain event cause the spill to reach surface waters?
- Are potable water wells in danger (either on or off the property)?

Step 3: Contact Appropriate Agencies

Make the following contacts:

1. Contact DEQ for advice/technical assistance as required in your facility permit.
    - All spills, regardless of volume or whether or not they reach surface waters must be reported to DEQ.
    - Records must be retained documenting spill and action taken to address the spill.
2. Call the nearest DEQ regional office at the locations shown in the appendix of your permit. Be prepared to provide the following:
    - Your name

- Facility name
- Telephone number
- Details of the incident (from Step 2)
- Exact location of the facility
- Location or direction of movement of the spill
- Weather and wind conditions
- Corrective measures taken
- Assessment of the seriousness of the situation

3. If spill leaves property or enters surface waters, call the local Emergency Management System (EMS).
4. Instruct the EMS to contact the local Health Department.
5. If you are unable to contact DEQ, the EMS, or the local Health Department, call 911 or the Sheriff's Department, and explain your problem to them. Ask them to contact the agencies as listed above.

Step 4: Implement Procedures

As advised by DEQ and the system design engineer, repair the system, and reassess the wastewater handling system to keep problems with off-site release of waste materials from happening again.

The emergency action plan must include provisions for emergency land application or transfer of wastewater from all wastewater storage structures in the system. This may include emergency pumping (to prevent overtopping of a storage structure) during periods when the soil or crop conditions are not conducive to normal application.

Note: DEQ must be contacted for guidance to land-apply wastewater in such instances.

You should consider which fields are best able to handle the wastewater without further environmental damage. Application rates, methods, and minimum buffer distances must all be addressed.

The emergency action plan should be available and understood by all employees at the facility:

- The main points of the plan along with the relevant phone numbers should be posted by all telephones at the site.
- A copy should also be available in remote locations or in vehicles if the land application sites are not close to the facility office.
- It is the responsibility of the owner or manager of the facility to ensure that all employees understand what circumstances constitute an imminent danger to the environment or to the health and safety of workers and neighbors.
- Employees should be able to respond to such emergencies and notify the appropriate agencies of conditions at the facility.

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